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Potato Tuber Production in Response to Reflected Light from Different Colored Mulches

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ABSTRACT

Colored mulches can affect the spectral balance (quality) and quantity of canopy light, which influences plant developmental patterns. Field studies were conducted to evaluate the influence of light reflected from different colored mulches on potato (*Solanum tuberosum* L.) tuber production. Potato plants ('Atlantic', 'Kennebec', 'Red Pontiac', and 'Superior') were grown in field plots covered with straw mulch that had been painted white, red, pale blue, or in alternating 5-cm stripes of blue and orange to provide a range of reflected light spectra. An unpainted straw mulch treatment and a no-mulch control were also used. Far-red to red (FR/R) ratio and percentage of photosynthetically active radiation (PAR) reflected from the different colored mulches relative to incoming sunlight ranged from 0.82 to 1.29 and from 12 to 46%, respectively. Plants receiving reflected light from the white, pale blue, and striped straw mulches produced >15% more marketable tubers than the no-mulch control plants. Red and unpainted straw mulches produced plants that had yields similar to the no-mulch control. Similarities in yield and spectral pattern between the unpainted straw mulch and the no-mulch control indicated that yield increases associated with painted straw mulches were due to alteration in the quality and/or quantity of light reflected from them. It was concluded that potato tuber production can be influenced by colored straw mulches.

PHOTOSYNTHATE production and distribution within the plant is influenced by the quantity and spectral balance (quality) of light intercepted by the crop canopy. The quantity of photosynthetically active radiation received by the plant predominately influences the rate of photosynthate production, whereas the spectral balance of light influences the distribution of assimilate within the plant.

Investigators have reported that the production of photosynthate is correlated to the quantity of PAR up to a saturation level (Baker and Musgrave, 1964; Hesketh and Moss, 1963). However, PAR intensities beyond the point of light saturation do not proportionately increase the rate of photosynthesis. The response curve of photosynthate production to PAR is well fitted to a parabolic regression equation.

Several studies have documented that the spectral balance of light intercepted by the crop canopy influences the distribution of assimilate within the plant (Kasperbauer, 1971, 1988; Kasperbauer and Karlen, 1986; Hunt et al., 1987, 1990a). Soybean [*Glycine max* (L.) Merr.] and wheat [*Triticum aestivum* L.] plants receiving end-of-day irradiation with red light (a low FR/R ratio) partition more photosynthate into the roots, whereas, plants irradiated with end-of-day far-red light (a high FR/R ratio) partition more photosynthate into the shoots. Regulation of developmental patterns by R and FR light has been attributed to the phytochrome system because the effects of R are reversible by FR, and vice versa (Borthwick and Hendricks, 1960).

Phytochrome has been assayed in the tips of potato tuber sprouts (Koukkari and Hillman, 1966) and Batutis and Ewing (1982) confirmed that phytochrome is involved in the photoperiodic regulation of potato tuberization. Brief exposure of potato shoots to R light in the middle of a 16-h dark period reduced tuberization, and this effect was reversed when the shoots were irradiated with FR light immediately following the R treatment.

The spectral balance of light within the crop canopy can be influenced by the number, proximity, and size of competing leaves, which reflect FR light and influence the FR/R ratio (Kasperbauer, 1987, 1988). The FR/R ratio of light within a soybean canopy was higher for north–south-oriented rows than for east–west-oriented rows (Kasperbauer, 1987). Differences in the spectral balance of canopy light, associated with row orientation, were attributed to heliotropic influences on FR reflection patterns, especially near the end of day. Soybean yield differences associated with row orientation were related to differences in the FR/R ratio of canopy light (Hunt et al., 1985; Kasperbauer et al., 1984). Kaul and Kasperbauer (1988) reported that higher yields of bush bean (*Phaseolus vulgaris* L.) with north–south-oriented rows were associated with greater shoot growth stimulated by a higher FR/R ratio of canopy light.

Hunt et al. (1989) reported that FR/R ratio differences in light reflected from different colored soil surfaces influenced the morphological development of soybean. Recently, colored mulches have also been used to manipulate the spectral balance of canopy light and various plant developmental patterns (Bradburne et al., 1989; Decoteau et al., 1988, 1989; Hunt et al., 1990b). The FR/R ratio of light reflected from red colored mulch was higher than from traditional black or white mulch, and tomato (*Lycopersicon esculentum* Mill.) and southern pea [*Vigna unguiculata* (L.) Walp.] yields were higher with red mulch than with black or white mulch. It was concluded that differences in the spectral quality of light reflected from the different colored mulches influenced yield via the regulatory effects of the phytochrome system.

Although the use of colored mulches for commercial potato tuber production is not economically feasible at present, it does serve as a practical research tool for the evaluation of canopy light effects on potato tuber production in field plots. Our objective was to determine if colored mulches can influence potato tuber production.

MATERIALS AND METHODS

A three-year field study was initiated in 1987 on a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Kandiudult) at the Coastal Plain Soil and Water Conservation

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Abbreviations: ANOVA, analysis of variance; DAP, days after planting; FR, far red; FR/R, ratio of far red to red; PAR, photosynthetically active radiation; R, red.

Research Center near Florence, SC. A completely randomized split-plot design was used, with colored mulches as the main treatments and potato cultivars as the sub-plot treatments with five replicates. Sub-plots consisted of single row plots (2.1 m long by 1 m wide) and were fertilized with 112, 224, and 224 kg ha^{-1} of N, P, and K, respectively. Metolachlor (2-chloro-*N*-[2-ethyl-6-methylphenyl]-*N*-[2-methoxy-1-methyethyl] acetamide) was applied prior to planting at the rate of 0.5 L ha^{-1} and incorporated into the soil.

Seed potato (Atlantic, Kennebec, Red Pontiac, and Superior) were treated with mancozeb (manganese ethylene bisdithiocarbamate) and planted on 26 Mar. 1987, 25 Mar. 1988, and 7 Apr. 1989, with 30-cm intra-row spacing. Straw mulches (S150 straw erosion control blanket; North American Green Co., Evansville, IN)[1] were painted either white (No. 148–0410; Southern Coatings, Sumter, SC), red (No. 159A110; Ace Hardware Corp., Oak Brook, IL), pale blue (No. BW79–9; Sherwin Williams Co., Cleveland, OH), or alternating 5-cm stripes of orange (No. 215–15; Day Glo Co., Cleveland, OH) and pale blue (No. 15469–1; Porter Paint Co., Louisville, KY) with an airless spray paint gun. Paints were used because they provide a convenient and effective method of producing colored mulches for small plot research. Red and white straw mulches were used in 1987, 1988, and 1989; the other colored mulches were used only in 1988 and 1989. Painted straw mulches were placed around the plants 34 DAP, when the plants were ≈25 cm tall. A no-mulch control was used each year, and an unpainted straw mulch treatment was included in 1988 and 1989. Tensiometers were placed in rows at a depth of 25 cm and irrigation water was applied with trickle irrigation tubing to maintain the soil matric potential below −25 kPa.

Spectral balances (quality) and quantities of PAR reflected from the different colored straw mulches were measured with a Model LI-1800 spectroradiometer (LI-COR, Lincoln, NE) equipped with a 1.5-m fiber optic probe and an integral hemispherical light collector (corrected remote cosine sensor window). The remote light collector was positioned 25 cm above the colored mulch and pointing downward, toward the mulch surface. Readings were taken each year at approximately 0900 h daylight time on a cloudless day, when the solar angle was ≈30°. Crop canopy heights, at the time when light measurements were taken, ranged from 26 to 38 cm. Light reflectance data presented in Fig. 1 are expressed as a percentage of incoming sunlight at each wavelength to determine the shift in the spectral balance due to colored mulch. The quantity of PAR (400–700 nm), red (640–650 nm), and far-red (730–740 nm) light reflected from the colored mulch surfaces were measured at 5-nm increments. Soil temperature at the 2.5 cm depth was measured with copper–constantan thermocouples coupled to a Campbell CR7 datalogger (Campbell Scientific, Logan, UT).

Potato tubers were harvested at ≈90 DAP. Tubers were graded, counted, and weighed. Tuber grades were: Grade no. 1 = tubers > 4.8 cm diam.; Grade no. 2 = tubers 3.8 cm < diam. < 4.8 cm; Grade no. 3 = tubers < 3.8 cm diam. Marketable yield consisted of Grade no. 1 and 2 tubers. Total yield consisted of marketable yield plus Grade no. 3 tubers. Data analysis was performed by analysis of variance and least significant difference by Statistical Analysis Systems (SAS, 1985).

RESULTS AND DISCUSSION

Spectral differences and quantities of light reflected from the surfaces of the colored straw mulches are presented in Fig. 1. Far-red to red ratios and PAR values of reflected light are reported relative to the FR/R ratio and PAR of incoming sunlight (i.e., values are expressed as a percentage of incoming sunlight being reflected by the different colored mulches). The FR/R ratios of reflected light from the different colored straw mulches ranged from 0.82 (striped mulch) to 1.29 (red mulch). Based on previous studies (Hunt et al., 1990a; Kasperbauer et al., 1984), the lower FR/R ratio of light reflected from the striped, white, and pale blue mulches would stimulate the plant to partition more assimilate into the root system. The higher FR/R ratio of reflected light from the no-mulch control and from unpainted and red mulches would stimulate the plant to partition more assimilate into the shoot. White, pale blue, and striped mulches reflected more PAR than the other treatments.

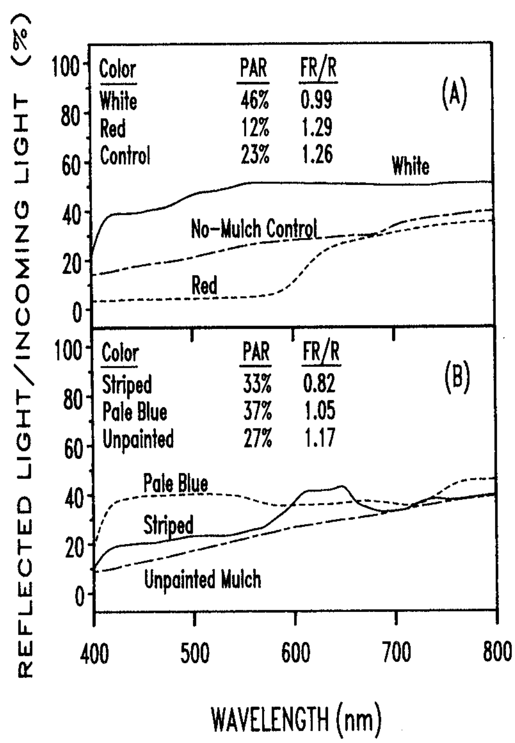

Fig. 1. Spectral distribution of incoming light reflected from different colored straw mulches. PAR = percentage of incoming light reflected from the straw mulch at 400–700 nm (photosynthetically active radiation); FR/R = ratio of far-red light (730–740 nm) to red light (640–650 nm) for light reflected from the mulches divided by the ratio of far-red light to red light in direct sunlight.

Soil temperatures at the 2.5-cm depth were similar for all straw mulches, with mean maximum and minimum values of 25.9 and 19.1 °C, respectively. Soil temperatures for the no-mulch control were slightly higher during the day (29.1 °C) and slightly lower at night (18.2 °C), as compared with the mulch treatment.

The influence of reflected light from the no-mulch control and from the red and white straw mulches on potato tuber production was evaluated for three years. The color × cultivar interactions were statistically nonsignificant ($P < 0.49$ for marketable yields; $P < 0.82$ for total yields). The data are therefore presented as means for all cultivars. Marketable and total tuber

[1]This paper reports the results of research only. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply approval to the exclusion of other products or vendors that may also be suitable.

Table 1. Yield and number of potato tubers as influenced by reflected light from red and white straw mulches, and a no-mulch control treatment in a 3-yr study in South Carolina.

Mulch color	Yield 1987	Yield 1988	Yield 1989	Yield Mean	Number 1987	Number 1988	Number 1989	Number Mean
	Mg ha^{-1}				no. ha^{-1} × 10^3†			
			Marketable yield					
White	31.0	28.6	15.0	25.1	108	105	53	89
Red	26.0	27.2	11.9	21.8	95	100	45	80
Control‡	25.8	24.7	9.9	20.3	94	95	39	76
LSD (0.05)	3.7	2.3	2.3	2.7	11	8	8	5
			Total yield					
White	34.2	32.0	18.7	28.3	161	150	107	139
Red	29.8	30.8	16.0	25.7	159	150	108	139
Control‡	29.3	28.7	13.5	24.1	151	147	92	130
LSD (0.05)	3.7	2.4	2.6	2.7	NS	NS	14	NS

† Actual values = reported values × 10^3.
‡ Control = No mulch.

yields were significantly ($P < 0.01$) higher with white mulch than with red mulch or the no-mulch control (Table 1). Plants grown with the white mulch produced 15 and 24% higher marketable tuber yields than plants grown with red mulch or the no-mulch control, respectively. Plants grown over red mulch had yields similar to the no-mulch control. These trends were consistent for all three years.

Even though the study was conducted in a noncontrolled environment, with its associated experimental error, it appears that differences in tuber yields are more closely related to differences in the FR/R ratio than the PAR of light reflected from the different colored surfaces. Treatments with similar FR/R ratios (red mulch and the no-mulch control) had similar tuber yields, whereas the white mulch treatment had a significantly higher tuber yield associated with its lower FR/R ratio. The lack of a direct correlation between tuber yields and PAR from the reflective surfaces may be due to the intensity of incoming sunlight, The PAR of incoming sunlight (>1200 μmol m^{-2} s^{-1}) was probably greater than required for maximum photosynthesis. Consequently, PAR from the reflective surfaces would have had minimal effect. Although the total number of potato tubers produced was not influenced by reflected light from the mulches, the number of marketable tubers was significantly higher with the white mulch (Table 1). Reflected light from the mulches did not seem to affect the initiation of tuber development, but reflected light from the white mulch did result in partitioning more photosynthate into the tubers, thereby producing more of the larger marketable tubers.

Additional colors of straw mulch were used in 1988 and 1989 to provide treatments with greater variation in the spectral balance of reflected light. An unpainted straw mulch with spectral characteristics similar to the no-mulch control was used to ascertain if other mulch-induced factors (i.e., moisture conservation and lower daytime soil temperature) were influencing tuber yields. Marketable and total tuber yields (weight and number of tubers) with the unpainted straw mulch were not statistically different from the no-mulch control (Table 2). These results support the hypothesis that yield differences associated with mulch color were due to differences in the spectral characteristics of reflected light.

Table 2. Yield and number of potato tubers as influenced by reflected light from different colored straw mulches in a 2-yr study in South Carolina.

Mulch color	Yield 1988	Yield 1989	Yield Mean	Number 1988	Number 1989	Number Mean
	Mg ha^{-1}			no. ha^{-1} × 10^3†		
		Marketable yield				
Striped‡	28.0	13.0	20.5	107	53	80
Pale Blue	29.5	10.3	19.9	104	47	76
Unpainted	25.3	10.5	17.9	95	44	70
Control§	24.6	9.2	16.9	95	39	67
LSD (0.05)	2.3	2.4	2.9	8	9	9
		Total yield				
Striped†	32.1	16.9	24.5	159	107	133
Pale Blue	32.9	14.4	23.7	151	110	131
Unpainted	29.1	14.5	21.8	146	105	126
Control‡‡	28.7	12.8	20.8	150	92	121
LSD (0.05)	2.3	2.6	3.0	12	16	11

† Actual values = reported values × 10^3.
‡ Alternate 5-cm wide stripes of orange and pale blue.
§ Control = No mulch.

Plants receiving reflected light from the striped and the pale blue mulches produced similar marketable tuber yields, which were >15% higher than with the no-mulch control. Reflected light from both the striped and pale blue mulches had lower FR/R ratios than the no-mulch control. These results are consistent with the hypothesis (Kasperbauer, 1987, 1988) that a lower FR/R ratio should favor belowground plant parts, whereas a higher FR/R ratio should favor increased shoot size and shoot-to-root biomass ratio.

Similarities in tuber yield between the striped and pale blue mulches cannot be readily explained by FR/R ratios. These similarities may have resulted from interaction with undefined spectral characteristics, such as blue light (400–500 nm). Thomas (1981) reported that blue light suppressed stem elongation in laboratory studies and Tanada (1984) hypothesized involvement of a light-quantity measuring system that he called heliochrome.

The data from this study show that colored mulches can alter the spectral balance and/or PAR of canopy light, which can influence potato tuber production. Future studies should include controlled-environment chamber experiments, which would provide for more controlled modification of FR/R ratios and PAR.

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